Precision Function Generator

MAX038 goes SMD

Klaus-Jürgen Thiesler

Although surface-mount parts are not the easiest to handle, the reward in test and measurement equipment is increased accuracy.

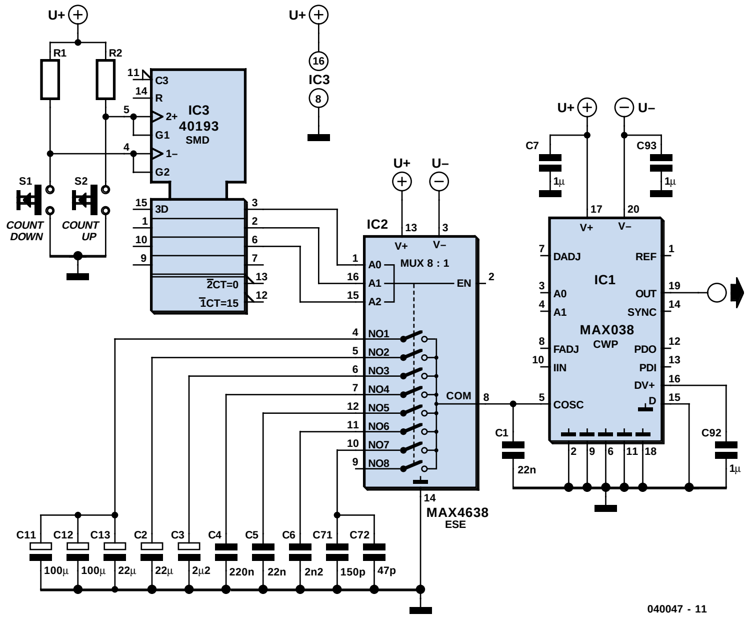

Figure 1. Suggested circuit diagram for a precision function generator based on the MAX038 (now in an SMD case.

Integrated precision function generator type MAX038 is now an old faithful with a history of ten years. In the June 1995 issue we described a full-blown function generator built from standard size parts and using what is now considered a large PCB. The project was hugely successful and PCB sales reached several thousands. In 1995, the use of SMDs in Elektor circuits was more or less prohibited because the advantages of a smaller board did not outweigh the disadvantages of problematic supply and mounting methods.

Today there's no way you can avoid SMDs anymore, however we generally do not use them unless they serve a good purpose, or if the component we wish to use is simply not or no longer available in 'leaded' form.

Other compelling reasons to use SMS are the ongoing miniaturisation of circuits and near elimination of stray capacitance and inductance (particularly in compact RF gear).

In some case, however, SMDs simply serve advancing technology — if you build the function generator from SMD instead of leaded parts and ensure low-inductance (i.e., *short*) PCB tracks then the instruments' technical specifications as well as its frequency range can be improved dramatically.

A digital frequency range switch in combination with multilayer ceramic capacitors (MLCC) in SMD technology not only improve the general performance of the MAX038 chip but also extend its frequency downwards to below 0.1 Hz and upwards to over 20 MHz. Such improvements we feel are worth just that extra effort in building up the circuit.

Two easily realised design aspects will help to unlock the full potential of the MAX038:

- an optimised PCB layout with the shortest possible copper tracks to keep stray inductance and capacitance to a minimum;
- SMD parts are marked by lower temperature coefficients and closer tolerances.

The circuit and PCB layout presented here do not represent a complete construction project. Rather, the publication aims at providing a few useful tips when you really want to juice the MAX038 for maximum performance. Hence Mr. Thiesler's contribution fills this month's Start Here pages.

Range switch

Instead of the mechanical range switch we propose an electronic CMOS analogue switch type MAX4638ESE, an 8-1 multiplexer that, depending on its control, connects the various frequency-determining capacitors to the internal oscillator. In the highest frequency range (20 MHz), it is essential for capacitor C8 to be connected directly to the MAX038 — and not by way of the multiplexer. Using the SMD stuffing in SO16 and 0815 enclosures this can be realised without problems. The ground side of C8 has to be connected directly to pin 6 (GND) — the other ground pins are unsuitable for that purpose.

The switching currents through the frequency determining capacitors are really low and the oscillator voltage (COSC) is just –1 V (at a supply of ±5 V). This makes the selection of the CMOS switch rather easy. Much more critical however is the PCB layout; 1 cm of 1-mm wide copper track representing an inductance of 7 nH. Long wires cause large stray capacitances and that is where SMDs are clearly superior to their leaded counterparts. As a bonus, SMDs are manufactured to closer tolerance specifications.

MLC capacitors

Solid, leaded, capacitors in the microfarads range are every expensive, inaccurate and bulky components and it is not surprising to see they are rarely used these days. SMD multilayer ceramic chip capacitors (MLCCs) are much more accurate, tiny and cheap mainly because they are manufactured by the millions for use in mobile phones. Mind you, MLCCs are not a new development — in fact they have been around for at least ten years. The codes stated in the parts list indicate the dielectric (X5R…) and the case shape (1210).

For the low end of the frequency range a 100-µF MLCC with a working voltage of 6.3 V is used with excellent results. Its ESR (equivalent series resistance) is stunningly low at less than 10 mΩ. A 100-µF, 68-µF and 22-µF MLCC stacked to make a neat pile was measured and found to have an equivalent capacitance of 216 µF.

Large value ceramic capacitors in X5R technology have a typical tolerance of ±20%, as opposed to +80/–20% for Y5V types. RF ceramic capacitors like the 22-pF MLCC with C0G structure and a maximum deviation of 0.5 pF are manufactured by, among others,

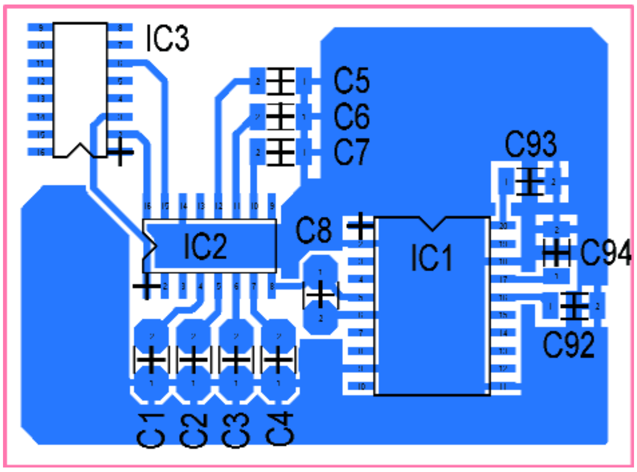

Figure 2. Proposed PCB layout featuring ultra-short tracks and an 8-way all-electronic frequency range switch.

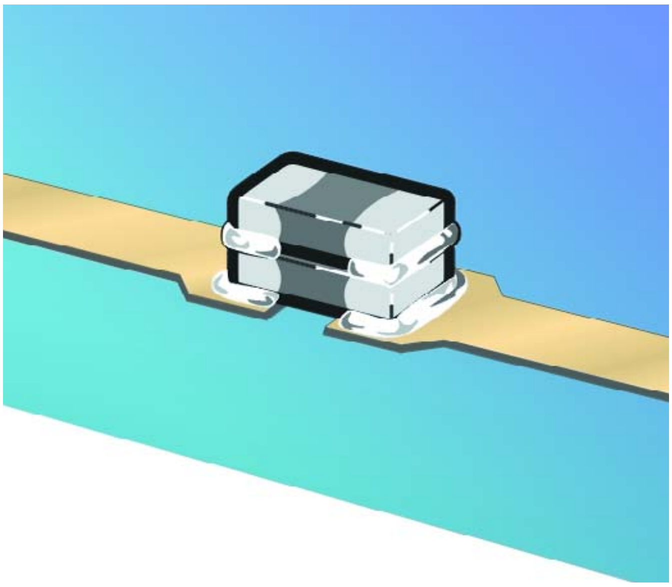

Figure 3. Capacitor stacking — no problem with MLCCs.

Taiyo Yuden. Although the temperature coefficient of just ±30 ppm (Class 1) is a bit over the top for our application, it does demonstrate the technological advances made by passive component designers. The author found that Reichelt (www.reichelt.de) supplies an assortment of 0805 style C0G ceramic chips at a reasonable price.

Adjustment requires a capacitance meter to be able to select the frequency determining capacitors for desired value, or combine a nmef of them to arrive at the desired values. These chip capacitors may be stacked onto each other and occupying just one pair of PCB solder pads. As you can see from Figure 3, the 'tower block' method helps to keep copper tracks as short as possible. For a change, you'll find that the trusty solder iron has the edge over industrial mounting methods like flow soldering or hot air! Although SMD components in 0805 and 1210 cases are really small, they can still be soldered manually if you have a steady hand.

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Components list:

Capacitors:

C1a,C1b = 100µF ceramic MLCC	Y5V	1210
C1c,C2 = 22µF ceramic MLCC	X5R	1210
C3 = 2µF2 ceramic MLCC	X7R	1210
C4 = 220nF ceramic MLCC	X5R	0805
C5 = 22nF ceramic MLCC	X7R	0805
C6 = 2nF2 ceramic MLCC	COG	0805
C7a = 150pF ceramic MLCC	COG	0805
C7b = 47Fp ceramic MLCC	COG	0805
C8 = 22pF ceramic MLCC	COG	0805

Semiconductors:

IC1 = MAX038CWP (SO-20)
IC2 = MAX4638ESE (SO-16)
IC3 = 40193 (SMD)

n	Frequency ranges		
	@ 2.2×10^n pF	**@ 4.7×10^n pF**	**@ 1.0×10^n pF**
8	0.1 - 1 Hz	0.04 - 0.4 Hz	0.2 - 2 Hz
7	1 - 10 Hz	0.4 - 4 Hz	2 - 20 Hz
6	10 - 100 Hz	4 - 40 Hz	20 - 200 Hz
5	100 Hz - 1 kHz	40 - 400 Hz	200 Hz - 2 kHz
4	1 - 10 kHz	400 Hz - 4 kHz	2 - 20 kHz
3	10 - 100 kHz	4 - 40 kHz	20 - 200 kHz
2	100 kHz - 1 MHz	40 - 400 kHz	200 kHz - 2 MHz
1	1 MHz - 10 MHz	400 kHz - 4 MHz	2 - 20 MHz